How to get a Ph.D. in Environmental Fluid Mechanics

Jan Kleissl
Assistant Professor, Dept. of Mechanical and Aerospace Engineering
University of California at San Diego
jkleissl@ucsd.edu, http://maereresearch.ucsd.edu/kleissl
Outline

• Timeline of an academic career in the US
• Graduate Study
• Dept. of Mechanical and Aerospace Engineering at UCSD
• My research
The academic career path in the US

Undergraduate study, 4 years
B.S. in Science/Engineering

Masters of Science (M.S.)
1-2 years

Doctoral Degree (Ph.D.)
4-6 years

Postdoctoral Fellow

Assistant Professor
After 5-10 years: Full Professor

Dipl.-Ing. Umweltschutztechnik
The doctoral degree (Ph.D.)

Admission

Departmental Qualifying Exam

Dissertation Defense

Classes

Research

Year
1
2
3
4
5

Masters

Product: Dissertation, consisting of 2-4 scientific publications
Work conditions

• 2-6 Ph.D. students / professor
• Strong relationship student-advisor, at least weekly research meetings
• International environment: 25% of Ph.D. students are US citizens
• Strong training in fluid mechanics, applicable to many environmental disciplines
Salary and Cost

- Teaching assistants / research assistants
- Stipend: US$ 1500-2000/month
- Additional cost to professor: US$ 1500/month for tuition
- Funding is based on research grants → 2-3 year planning in advance

- For reference:
  - movie ticket: $8, rent: $500, beer: $3, gas: $0.6/l, surfboard ???
The Department of Mechanical and Aerospace Engineering
University of California at San Diego

Degrees in:

- Aerospace Engineering
- Mechanical Engineering
  - Solid Mechanics
  - Nano Science
  - Fluid Mechanics
- Environmental Engineering
  (Environmental Fluid Mechanics)

50 faculty total, 10 faculty in (Environmental) Fluid Mechanics, e.g.
- Ocean boundary layers
- Direct numerical simulation, Large Eddy Simulation
- Natural ventilation
- Stratified flows
Example Research Topic: Natural Ventilation

Steady displacement flow (buoyancy driven)

Transition (5 sec)

Transition (15 sec)

Steady mixing flow (wind-driven)

Linden et al. JFM 2004
My research: Environmental Fluid Mechanics - Micrometeorology

- Atmospheric boundary layer flows are important since they drive the transport of heat, water vapor, CO2 etc. from/to the earth’s surface
- Atmospheric flows are difficult to model due to surface heterogeneities
- Necessity for measurement and simulation on the microscale (< 5 km)
- Application of turbulence numerical simulation (Large Eddy Simulation) and measurement (large aperture scintillometer) techniques
Blending of Surface Heterogeneities

\[ \frac{\partial u}{\partial z} - \left( \frac{\partial u}{\partial z} \right)_{xy} \]

Brutsaert 1998

Patches of varying roughness

Bou-Zeid et al. 2005
LES of atmospheric flow – Application to evaporation and the hydrologic cycle

\[ O(10 \text{ m}) \sim \Delta \]

Mean stream-wise velocity \( u \)

\(~ O(1 \text{ km})\)

~ O(5 km)

\(~10^7\) grid points → needs to be run on supercomputers
Application: Ground truthing for hydrologic remote sensing algorithms

- Ground truthing for SEBAL\textsuperscript{NM}
- Large Aperture Scintillometer (LAS): Principle of operation
- LASs for Hydrology: The New Mexico Tech LAS Network
- Preliminary validation results from SEBAL applied to MODIS for July 2006
Energy balance can be used to estimate LE:

\[ \text{LE} = R_{\text{net}} - G - H \]
SEBAL ET from Landsat / MODIS

Hot pixel: \( ET = 0 \rightarrow H = R_n - G \)

\[ H = \rho c_p dT / r_{ah} \]

Cold pixel: \( H = 0 \)

Hong, Kleissl et al. WRR 2006
From Cn2 the sensible heat flux can be derived over a distance of 1 – 5 km.
Magdalena Ridge
Mountainous Grassland

San Acacia
Riparian Area

Valle Grande, VCNP
Mountainous Grassland

Base of M-mountain Desert
Footprint of LAS measurements

- Model by Hsieh et al. 2000
- Footprint weighting function for each pixel

→ peak of weighting function is usually within 1km x 1km pixel from transect center
### Results

<table>
<thead>
<tr>
<th>H [W m^{-2}]</th>
<th>LAS</th>
<th>SEBAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>VCNP</td>
<td>222-306</td>
<td>221-278</td>
</tr>
<tr>
<td>Sevilleta</td>
<td>328-376</td>
<td>286</td>
</tr>
<tr>
<td>San Acacia</td>
<td>215</td>
<td>112-167</td>
</tr>
</tbody>
</table>
Conclusions

• NMT-LASNet completed
  → NM ideal for ground truthing
• Large Aperture Scintillometers provide reliable estimates of H over footprints similar to MODIS pixels
• Future Research:
  – Analyze more images & sites
  – Include surface temperature, downwelling shortwave radiation measurements
  – Calibrate SEBAL\textsuperscript{NM} using LASNet
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  – MRO: Dan Klinglesmith
  – VCNP: Bob Parmenter, Johnny, Albert, & Juglio, Karen Montgomery (DGPS)
  – Sevilleta: Renee Robichaud, Mike Friggens
  – El Malpais: Jeff Albers, Herschel Schulz